Assessment of Water Quality in Virginia's Non-tidal Streams using a Probabilistic Sampling Design

Mary R. Dail, George J. Devlin, Jason R. Hill, Dr. Michael J. Scanlan, William J. VanWart, and Dr. Lawrence D. Willis

Virginia Department of Environmental Quality, 3019 Peters Creek Rd, Roanoke, Virginia 24019

ABSTRACT

The Virginia Department of Environmental Quality's (VDEQ) biological and ambient water quality monitoring programs have historically used a targeted approach for monitoring the Commonwealth's aquatic resources. This sampling method is necessary for monitoring regulatory compliance of pollution sources and tracking local pollution events. However, the data produced by the targeted method is difficult to use in estimating water quality conditions across the entire state or a river basin. In 2001, VDEQ began a five-year probabilistic monitoring program (ProbMon) for non-tidal streams. ProbMon incorporates a random tessellation stratified survey design that allows us to produce an accurate assessment of chemical, physical, and biological conditions in 1st through 6th order streams. This is the first survey that will provide policy-makers and the public with estimates of the status of Virginia's aquatic resources with statistical confidence. Additional objectives include establishing ecoregion reference sites and conditions for integration into the current biological monitoring program. First year results include data from 63 sites where VDEQ sampled benthic macroinvertebrates including physical habitat and 58 sites where VDEQ sampled water chemistry. Watershed land cover was also evaluated at each site, showing wide variations in percentage of urban, agricultural, and forested land cover.

INTRODUCTION

ProbMon is a monitoring and assessment program that provides statistically based information about water quality in Virginia. The target population is all non-tidal perennial rivers and streams in Virginia. ProbMon is based on EPA's Environmental Monitoring and Assessment Program (EMAP) techniques (Olsen 1999). At VDEQ's request, ProbMon sampling locations were generated in a fashion similar to EMAP sites by EPA's Office of Research and Development in Corvallis, Oregon. The survey provides policy-makers and the public with 1) estimates of the geographic coverage and extent of the aquatic resource conditions with known confidence; 2) estimates of the current status, trends, and changes in indictors of Virginia's aquatic resources with known confidence; 3) statistical summaries and assessments of Virginia's aquatic resources; and 4) a description of associations between indicators of natural and anthropogenic stressors and the condition of aquatic resources.

STUDY DESIGN

ProbMon used a random tessellation stratified survey design to select stream sample sites (Stevens 1997). In this method an EMAP grid of hexagons was placed over the Commonwealth of Virginia. This grid ensures randomization and spatial distribution of sampling locations. The base density is one grid point per 640 km². This was intensified to allow regional analyses. Because Strahler stream order is expected to be an important determinant of aquatic condition, the random selection of sites was arranged so that approximately equal numbers were chosen from 1st - 4th and 5th-6th order streams each year. Because of the random selection process, the numbers were not exactly equal this year, a condition which is expected to even out over the five years of the study.

EMAP Hex
(640 km²)
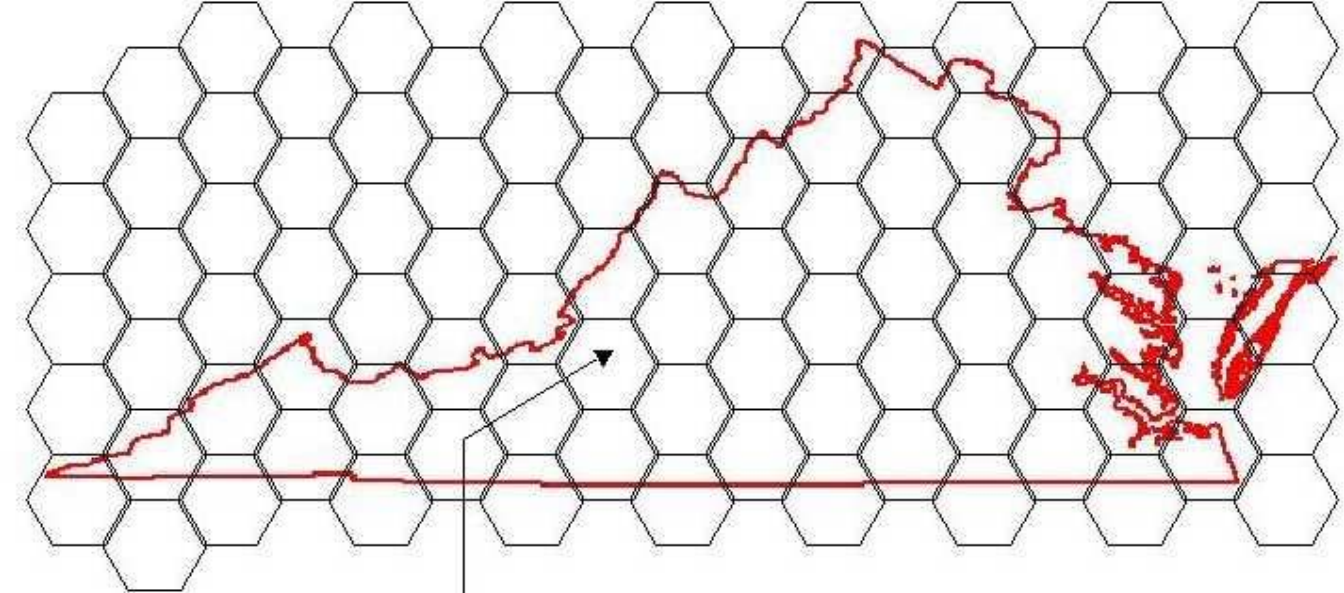
STATION LOCATIONS

ProbMon coverage over five years (n=300). One of the ProbMon survey goals is to identify trends and patterns by ecoregion. An ecoregion is the region of relative homogeneity, of similar land surface form, soils, land uses, and potential natural vegetation, in an ecological system (Omernik 1987, Bailey 1976). There are sufficient samples in most ecoregions to accomplish this goal by the end of the study.
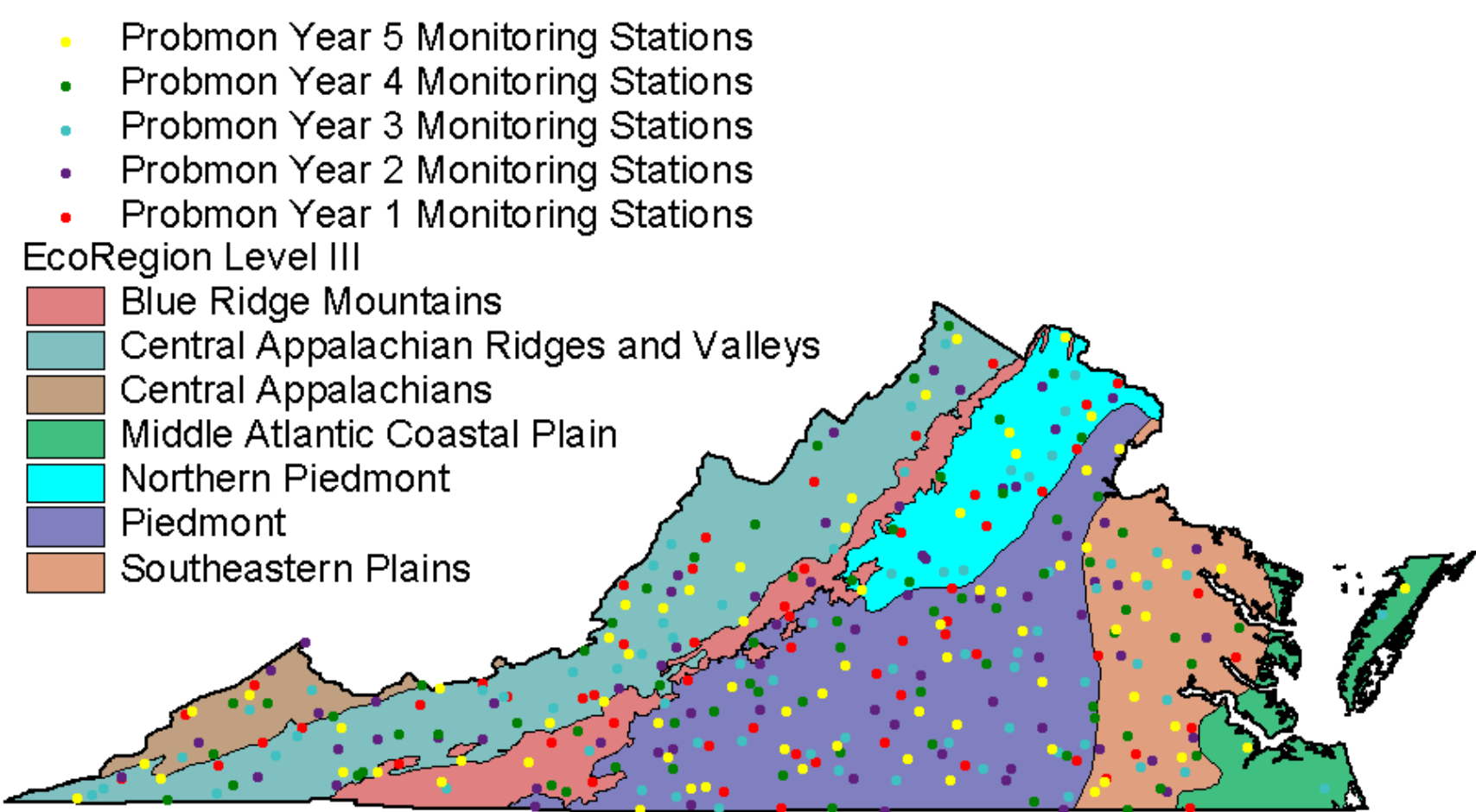

METHODS

Data Analysis

Boxplots were created through STATISTICA 5.1 to permit the comparison of ProbMon variables by Strahler order. Maps of relative values are a second method employed to detect patterns. Because samples were collected across Virginia, any geographic patterns might best appear in maps showing relative values at the collection sites. The third method of analysis involved the manipulation of the data to generate the cumulative distribution function (CDF) for key variables. The CDF is a statistical function that has been under utilized in environmental studies. However, it can also provide the probability that a variable would be above a threshold or that it would be within a certain range. For VDEQ's ProbMon, these probabilities apply to the target universe, all non-tidal streams in the Commonwealth.

CHEMICAL RESULTS

An estimate of overall exceedance of the dissolved oxygen (DO) standards is sought through the CDF curve. The CDF curve below suggests that approximately 9% of Virginia stream kilometers have fall DO concentrations below 4 mg/L. The 95% confidence interval for that estimate is 0% to 18%.


Dissolved Oxygen (Fall 2001)
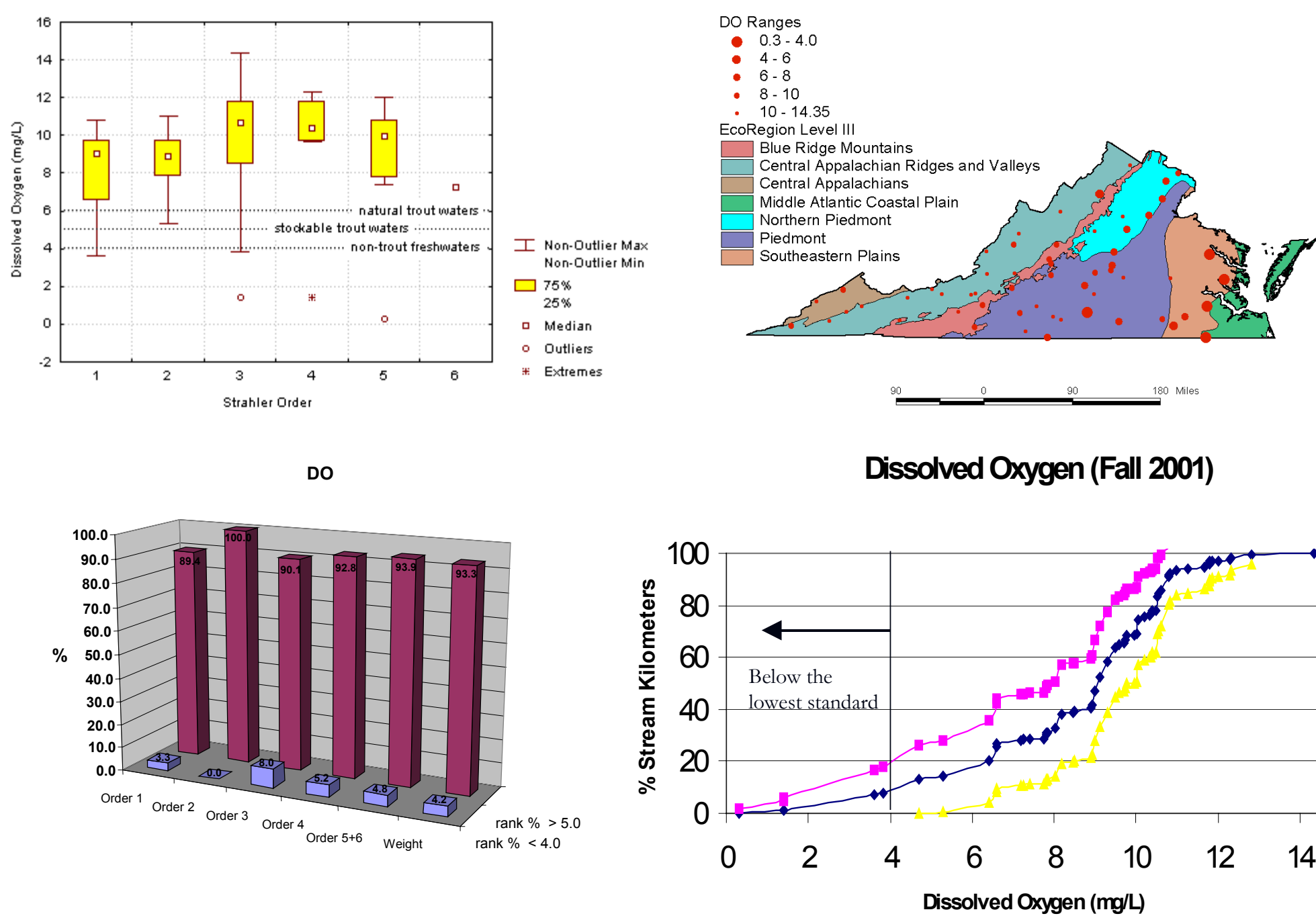
BIOLOGICAL RESULTS

EPT is an abbreviation for the aquatic insect Orders Ephemeroptera (Mayflies), Plecoptera (Stoneflies), and Trichoptera (Caddisflies). The EPT Index is the number of Families in the three Orders. The majority of the Families in the EPT orders are intolerant of pollution and other environmental stressors. The EPT Index is a Richness metric. Based on the CDF curve, 35% of non-tidal stream kilometers have eight or more EPT taxa indicating communities with a diversity of pollution intolerant taxa. Meanwhile, 50% of the stream lengths had four or fewer EPT families, indicating a low diversity of sensitive taxa.
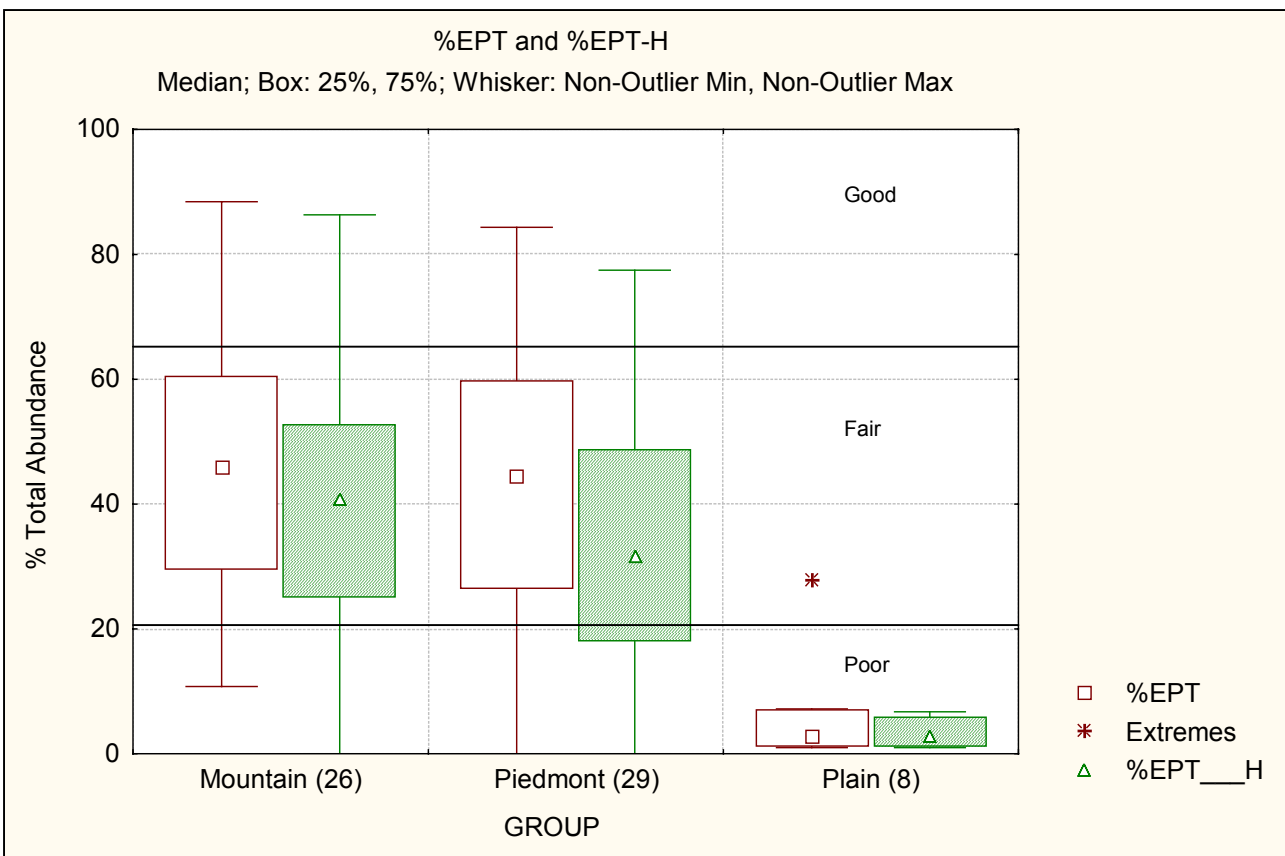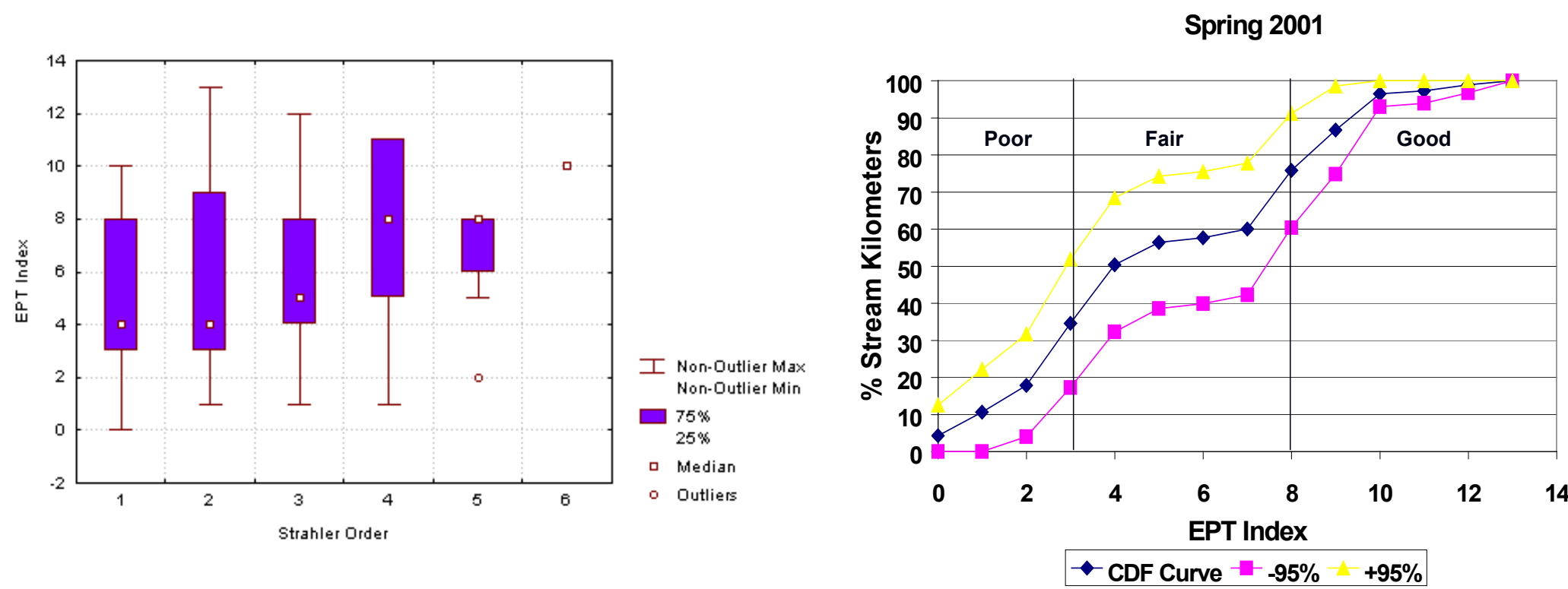

HABITAT RESULTS

Habitat quality is an expression of the physical conditions in a stream channel, the surrounding riparian zone, and the watershed land use. The quality and quantity of available habitat can have a large influence on the ecological integrity of a stream. The habitat quality at each ProbMon site was judged through ten Rapid Bioassessment Protocol (RBP) habitat parameters adapted from Barbour et al. (1999). Each field site was given a score between zero and 20 for each parameter, with zero being the poorest quality and 20 the best. Scores for each parameter can be translated into four qualitative categories ranging from optimal or least disturbed, to poor or very disturbed.
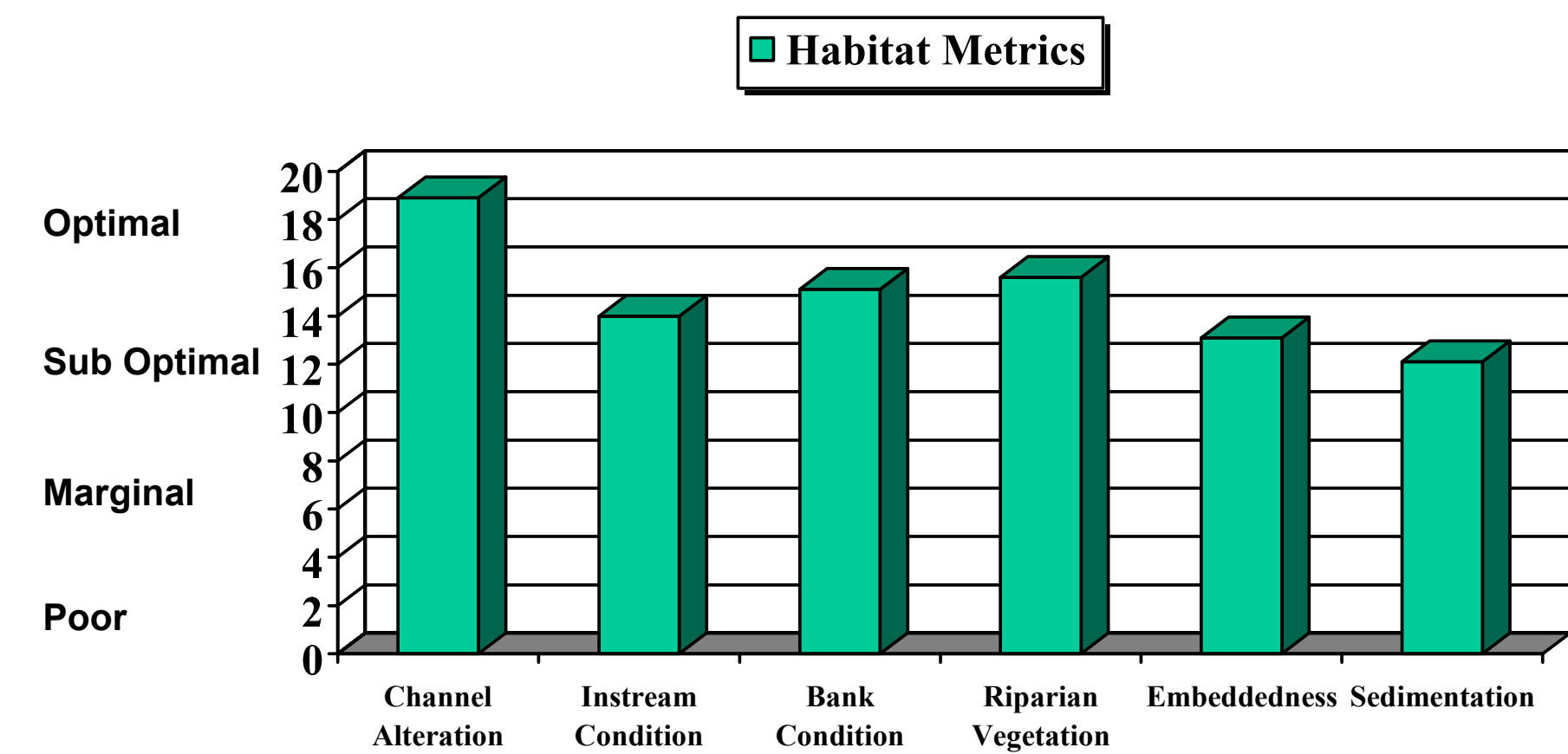
LAND COVER (Multi-Resolution Land Characteristics)

By calculating land cover upstream of ProbMon sites, VDEQ can explore the impact of different land covers on stream conditions. If land cover can be used to predict stream conditions then an immediate use of land cover data is to help VDEQ biologists identify reference sites. Reference sites are stream segments that have exceptionally good conditions for benthic macroinvertebrates. Land cover is not compared to chemical, physical habitat or biological data in this report. However, the availability of recent digital land coverages for Virginia holds great potential for explaining the chemical, habitat, and biological conditions observed at sample points across the Commonwealth.
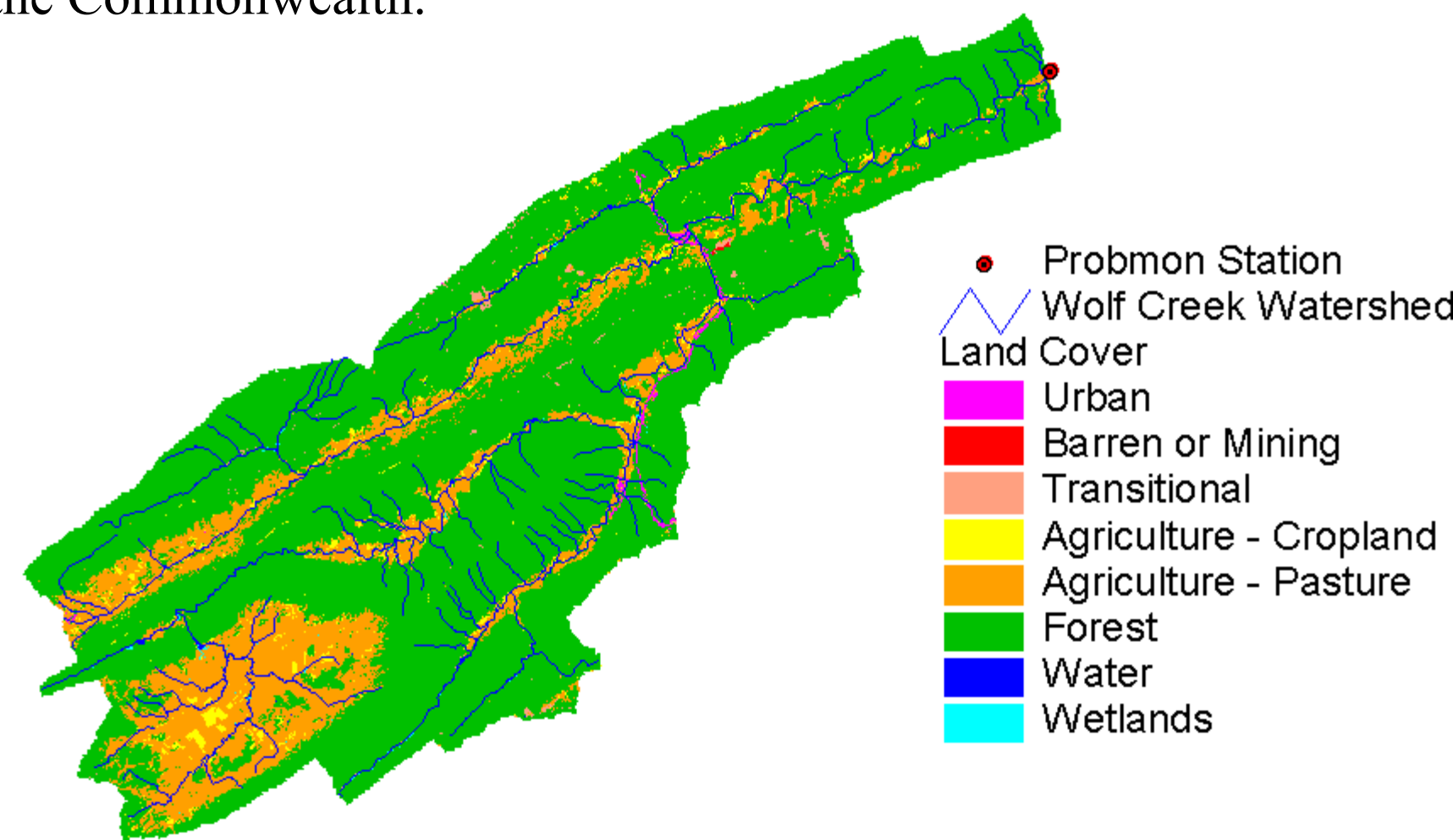
SUMMARY

The first sample year of the Probabilistic Monitoring Program (ProbMon) in the Commonwealth was 2001, the year covered by this report. All sites were randomly selected by the USEPA using a stratification method developed in the EMAP program. The great value of random sites is that the estimates from the data apply to the entire population. The habitat and benthic macroinvertebrates were sampled both spring and fall, at 63 sites. Only the spring data was analyzed in this report because macroinvertebrate communities are in their best interpretive condition in that season. Water chemistry was sampled in the fall at 58 sites.

ACKNOWLEDGEMENTS